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Measuring Earth Radiation Budget Using Constellation of Sensors on NEXT

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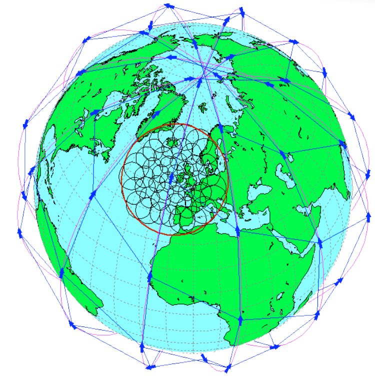
NEXT Hosted Payload Opportunity

NEXT upgrades & replaces current 66 satellite LEO constellation, anticipated to begin launching in 2014

- Compatibility with current fleet eases network transition
- Capability to host payloads on every satellite is built in
- Prime contractor selection between Lockheed Martin and Thales Alenia Space by summer 2010
- **Unique opportunity** to host 66 Earth observation payloads on NEXT
  - Weather and climate observations, remote sensing, space weather, space situation awareness and (many other DoD applications), scientific experiments targeted for small satellite programs (e.g. Cubesats)
- **Way to address current critical needs** for monitoring global climate and environmental changes
  - Decadal Survey recommendations for weather and climate, fill data gaps for remote sensing, and weather/space weather data from NPOESS realignment, and restructuring
- **Public-Private Partnership business model to enable cost effective** sharing of commercial investment in space infrastructure with DoD and other agencies



Iridium NEXT Specifications	
Constellation	66 satellites in 6 orbital planes
Orbits	Polar
Altitude	780 km
Inclination	86.4°
Orbital period	101 minutes
Expected Launch Window	2014-2016
Risk mitigation	Multiple in-orbit spares, redundant backup Earth station

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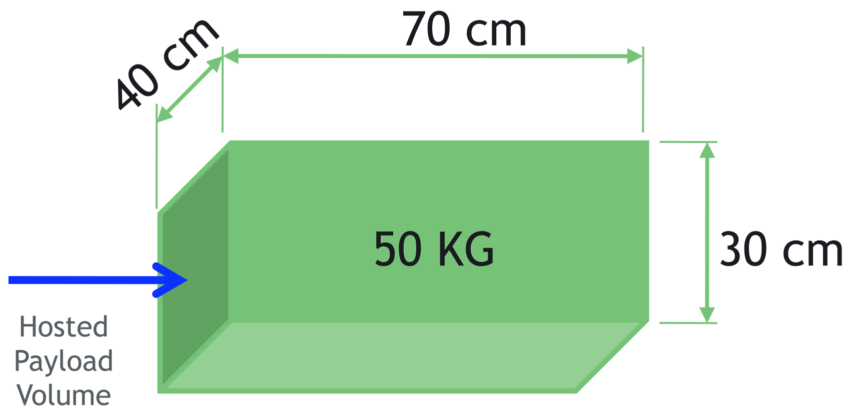
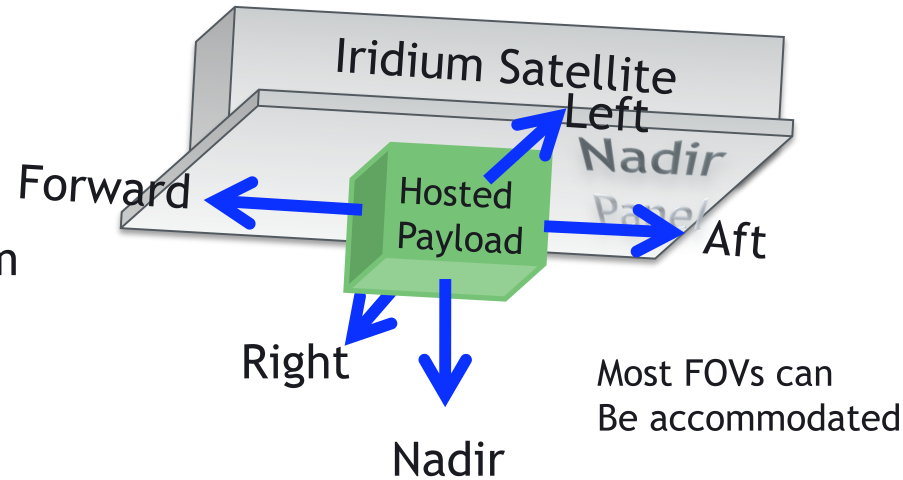
NEXT Hosted Payload Specification



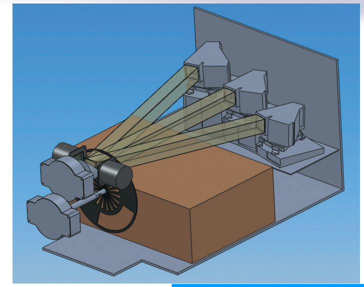


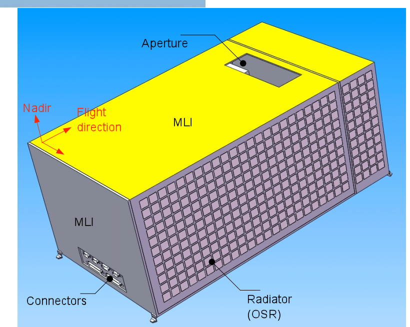
Iridium NEXT Hosted Payload Specifications	
Weight	50 kg
Payload Dimensions	30 x 40 x 70 cm
Payload Power	50 W average (200 W peak)
Payload Data Rate	<1 Mbps, Orbit average ~100Kbps

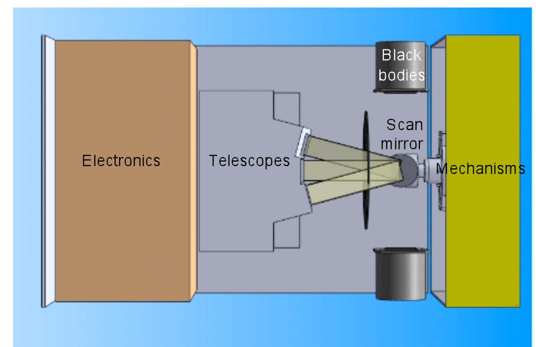
NEXT ERB Description

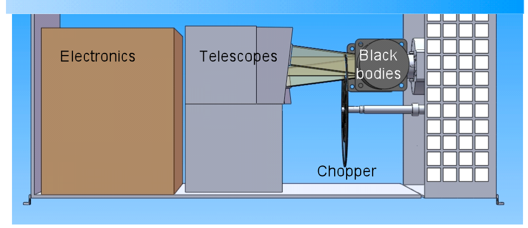
- Utilize Broad Band Radiometer (BBR) (delivery 2013) from EarthCARE mission for ESA as the baseline for NEXT. Heritage from GERB. Built by SEA and RAL
- Iridium NEXT Broadband radiometer; covers 0.2 to 100 um, is smaller and fits well within desired SWaP
- The proposed solution consist of twelve broadband instruments (2 per plane) and associated imager for scene identification and cloud classification
- Detailed study demonstrated this solution provides real-time data delivery, full globe coverage with a swath of 1000 km, resolution of 10 km at nadir, and 3 hour resolutions at the equator
- Deep Space view is not required, and exported torques are about the axis preferred by the spacecraft

A high heritage ERB instrument is being proposed for Iridium NEXT

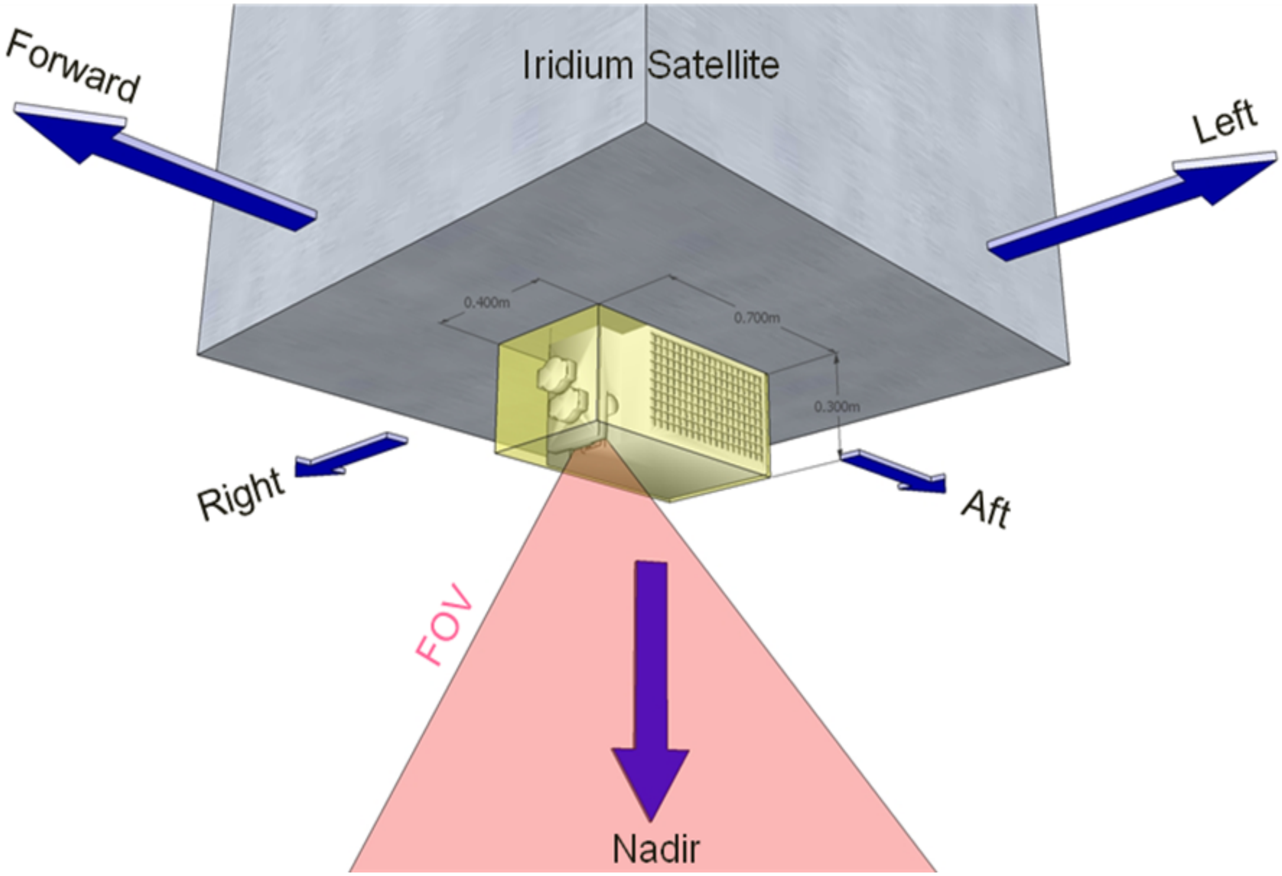








ERB Accommodation on NEXT



The ERB payload accommodation details are complete for NEXT designs, no major are issues seen

Coverage from ERB Sensors in NEXT Constellation

- Table below shows revisit times in hours for 95% coverage, for a variety of instrument accommodation in NEXT orbital planes

Instrument swath

Number of instruments per plane

Number of planes used

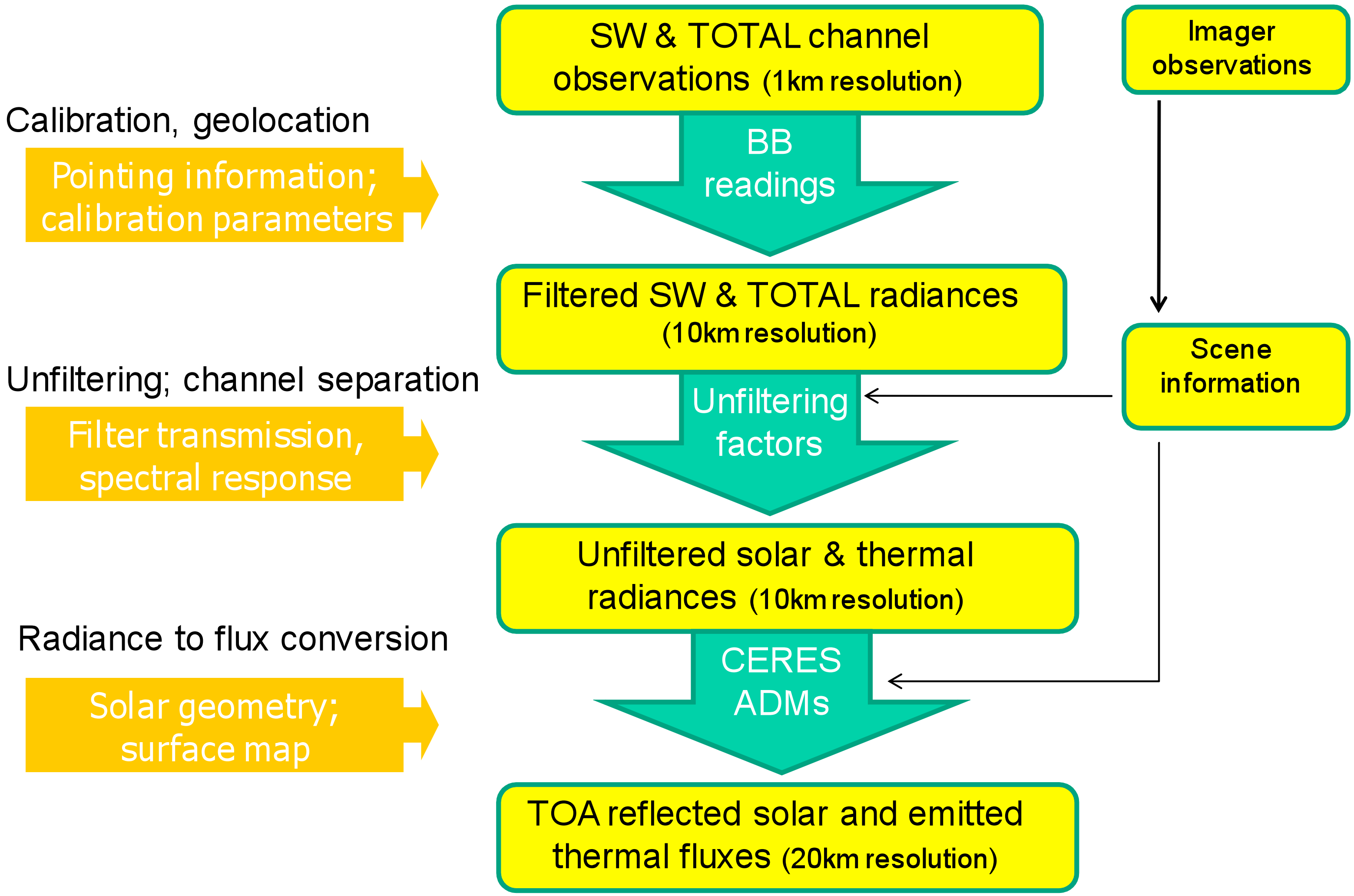
Relative positioning (in true anomaly) of instruments between planes (P) and within the planes (S)

Worst revisit time for 95% of globe

Swath Width (Km)		Satellite Configuration per Plane											
	# Planes	6 (RA = 30°)										2 (RA = 90°)	3(RA = 60°)
	# Sats	1		2					3		11	6	4
	MA(P)	49°	114.5°	114.5°	81.8°	49°	81.83°	212.75°	16.37°	81.83°	16.37°	212.75°	32.73°
	MA(S)	N/A	N/A	32.73°	163.6°	32.73°	98.19°	163.65°	130.92°	32.73°	32.73°	163.65°	65.46°
500		62.2	27.1	20.6	10.9	17	7.3	7.7	4.8	7.7	1.3	12.4	6.9
1000		6.4	11.6	5	3.8	5.8	3.5	3.3	1.9	3.7	1.1	5.2	4
1500		5.5	3.9	3.7	2	4.5	2.7	2	1.6	3.3	0.8	5	3.4

- Placing 2 instruments in each of the 6 planes (i.e. 12 instruments) leads to <3hr coverage at equator, provided the instrument swath is 1500km

Instantaneous ERB Product Generation



Instantaneous ERB Product Errors

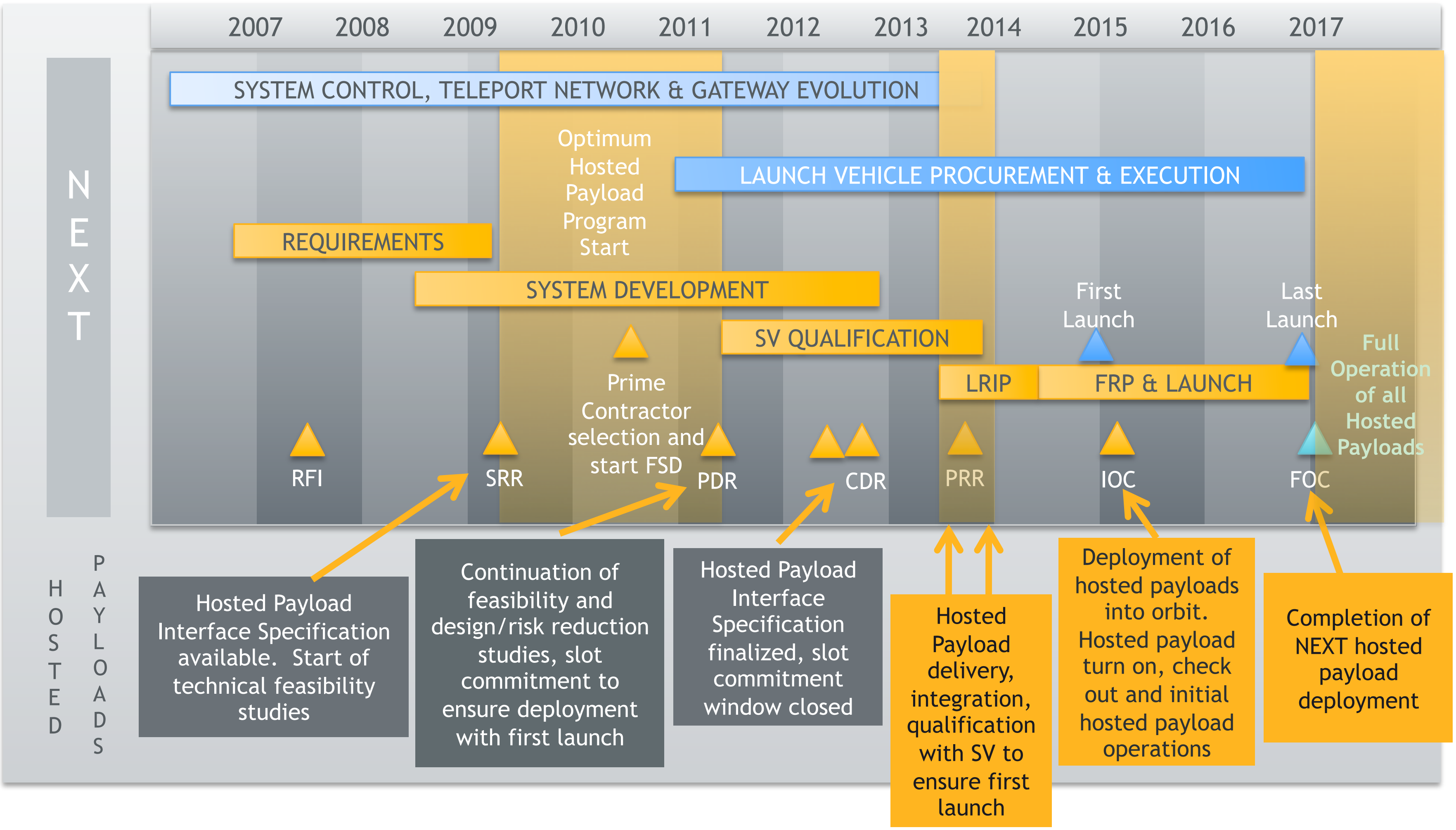
Instantaneous errors (at 20km resolution)	Solar		Thermal	
	Noise	Bias	Noise	Bias
Filtered radiance (expected spec) Noise is detector noise, bias is start of life due to gain uncertainty due to ground calibration	$0.32Wm^{-2}sr^{-1}$	1%	$0.32Wm^{-2}sr^{-1}$	0.5%
Stray light / background subtraction		$0.42Wm^{-2}sr^{-1}$		$0.19Wm^{-2}sr^{-1}$
Polarisation (expected spec)	< 0.3%	-	<0.2%	-
Interpolation Instantaneous products not interpolated except to match SW and TOTAL	N/A	N/A	95% cases $< 1Wm^{-2}sr^{-1}$	None
Unfiltering / channel separation Noise due to scene scatter around fit to available information, bias due to spectral response uncertainty, assumes calibration source spectra, instrument spectral response and imager performance.	1.2% (using imager for cloud fraction)	1%	0.4% (direct unfiltering)	0.9%
Spectral overlap correction Noise due to scatter around fit to available information, assumes instrument spectral response	$0.1Wm^{-2}sr^{-1}$	-	$0.35Wm^{-2}sr^{-1}$	-
Unfiltered radiances (RMS combination of errors, example scene)	$2.80Wm^{-2}sr^{-1}$	$3.21Wm^{-2}sr^{-1}$	$1.16Wm^{-2}sr^{-1}$	$0.74Wm^{-2}sr^{-1}$
	$225\ Wm^{-2}sr^{-1}$ scene		$80\ Wm^{-2}sr^{-1}$ scene	
ADM (varies with geometry and scene, mid-values given from CERES TRMM validation)	$10\ Wm^{-2}$	-	$5Wm^{-2}$	-
Scene ID (assumed imager spec)	$15\ Wm^{-2}$	0.5%	$10Wm^{-2}$	1.8%
TOA outgoing fluxes (RMS combination of $\pi\times$radiance error and flux errors)	$20Wm^{-2}$	$11Wm^{-2}$	$12Wm^{-2}$	$5Wm^{-2}$
	$700\ Wm^{-2}$ scene		$250\ Wm^{-2}$ scene	
Incoming solar (noise/bias from daily variability and solar constant uncertainty resp)	$1\ Wm^{-2}$	$1\ Wm^{-2}$		
TOA net flux (RMS combination outgoing and incoming SW flux errors)	$20Wm^{-2}$	$11Wm^{-2}$		
Stability over mission life		1%		0.3%

NEXT Solution Compared to CERES

- Generation of instantaneous products similar to CERES in many ways and capable of comparable accuracy dependent on instrument noise, calibration and imager properties.
  - Unfiltering based on filtered radiances, scene information and theoretical unfiltering factors
  - Radiance to flux conversion achieved with the CERES TRMM empirical ADMs
  - Absolute accuracy and stability is lower than CERES however
- Comparison with CERES
  - Common components of optical system for both channels in BBR improves stability of LW
  - Footprint sub-sampling improves interpolation accuracy and co-registration of channels, and hence channel separation. Also increases frequency of broad-band clear observations improving average clear sky products
  - High temporal sampling of the globe, covering full diurnal cycle enabling average products without additional observations or interpolation

Iridium NEXT Hosted Payloads

Decision Time Line



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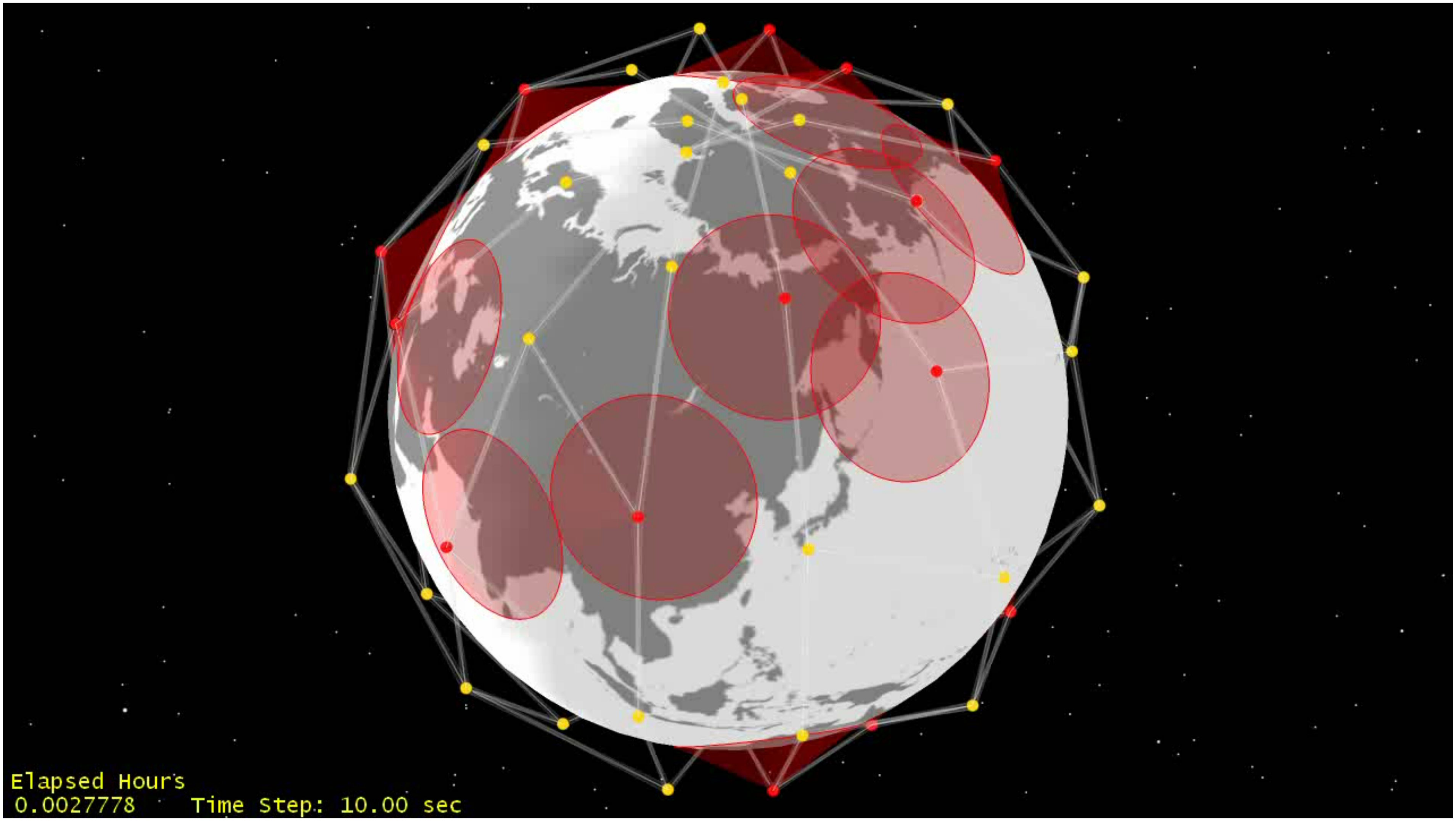
NEXT ERB Solution Summary

- A NEXT ERB sensor largely derived from the EarthCARE BBR can meet ERB requirements
  - Geometry requires some changes, but most subsystems can be used within qualification heritage; others (e.g. telescope) are low risk
  - Mass, power and volume are compliant with SV interface requirements
- Most significant change is the potential need for a visible or window channel for scene characterization in support of the flux-to-radiance conversion
- 2 sensors per plane (12 instruments) with 1500km swath can achieve breakthrough requirement (<3hr refresh rate), however to optimize cost vs. performance 1000 Km swath may be acceptable
- A budgetary ROM cost has been established and represents a fraction of costs for dedicated missions
- ERB community can benefit by taking advantage of this opportunity and launching 12 instrument on NEXT

Data from 12 sensors on NEXT LEO constellation used synergistically with CERES, can improve upon the current CERES state of the art (GEO) products

NEXT ERB – 18 Sensors



Thanks !!

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